

LETTERS TO THE EDITOR.

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Radium-D and the Final Product of the Radium Disintegration Series.

A RECENT discussion in the columns of NATURE has raised the question of the existence of elements chemically and spectroscopically identical but differing from one another by a few units of atomic weight. Should the far-reaching generalisations of Soddy and of Fajans prove correct, the chemical elements will have to be regarded from an entirely different point of view, and the explanation of the periodic nature of their properties will have to be sought for in the recurrent character of the processes of radio-active disintegration. At present, however, some of the evidence on which those views are based is at least open to question. With the exception of radium, niton, and the parent elements—uranium and thorium—none of the thirty-four radio-active bodies have been isolated, and none of their compounds have been obtained in a state approaching purity. Their properties have only been inferred from their behaviour when mixed with very large amounts, comparatively speaking, of known elements, such as lead, thorium, and tellurium, and when it has been found impossible to alter the proportions of these minute traces of radio-active matter by the usual analytical processes, chemical identity has been inferred. Even admitting the extreme delicacy of radio-active methods of analysis, it might be questioned whether much can be deduced from the inseparability of such minute traces when present along with large amounts of closely related elements. More satisfactory evidence would be furnished if the chemical properties of an equilibrium mixture from a pure radio-active parent could be investigated; and since during the last few months some direct observations have been made on the nature of radium-D and its products it may be of interest to give a preliminary account of the investigation.

The source of the radium-D and its products was highly purified niton (radium emanation) which four years ago had been compressed into fine capillary glass tubes, liquefied, and used for the determination of the vapour pressures of the gas by Sir William Ramsay and myself. Each tube originally contained somewhat less than 0.2 of a curie of emanation, which, when liquefied by pressure, filled a volume of approximately $1/5000$ cub. mm. at the sealed end of the tube. Three tubes of the precious material were kindly placed at my disposal by Sir William Ramsay. The emanation was allowed to decay under pressure, and subsequent microscopic examination showed that the liquid had transformed itself into a dark-coloured deposit of submetallic lustre, resembling somewhat a dried colloidal metal, and also into a colourless gas, viz. helium. The total mass of the solid deposit was hence of the order of $1/1000$ milligram, and since it had decayed for four years it contained, in addition to the equilibrium quantities of radium-E and radium-F, about 15 per cent. of radium-G, the end point of the series, as well as traces of the branch series derived from radium-C₂. The tube was only weakly radio-active, but when laid on a photographic plate the impression produced by the β -radiation of radium-E corresponded exactly with the visible distribution of the deposit in the tube. By a suitable procedure the mercury sealing the open end of the

tube was removed as completely as possible, and after pumping off the helium pure chlorine was admitted. At ordinary temperatures the submetallic deposit remained unattacked, but on gently warming it was seen to change completely into a pure white, apparently homogeneous, crystalline chloride. On heating *in vacuo* to 220° C., the chloride did not volatilise perceptibly, and the photographic impression it produced coincided with that obtained from the submetallic deposit. Hence the chlorides of radium-D, -E, and -G are not appreciably volatile under these conditions.

On introducing water into the tube it was seen that the crystalline deposit dissolved without decomposition, but was only slightly soluble. Even after warming in presence of about ten times its own volume of water only a small proportion of the total solid went into solution.

The chief object, however, of this experiment was to determine whether radium-G, the final product of the series, was similar in chemical character to lead, and also to find out if radium-D approximated closely in behaviour to its longer-lived descendant. That radium-G and lead are identical is supported by much indirect evidence, though no direct proof has been advanced. Now lead is an element which can be detected in very minute quantities by the delicate and characteristic microscopic test of Behrens, viz. by the formation of a characteristically crystalline triple nitrite with the nitrites of copper and potassium. The test is so delicate that $1/100,000$ milligram of lead can be detected with certainty if the proper conditions are observed, and, moreover, by determining the number and size of the crystals in a drop of known volume the amount present can be approximately estimated. It was proposed, therefore, to apply the test to a known fraction of the radio-active matter in the tube and to see whether the amount of triple nitrite formed corresponded with radium-G alone or with radium-G + radium-D. The application of the test was complicated, however, by the discovery that the glass of the capillary, and, in fact, soda-glass in general, contained about 0.03 per cent. of lead, and that a detectable fraction of this lead could be dissolved out of the glass with nitric acid. By avoiding the use of strong acids and simply extracting the glass with water no perceptible amount of this element could be found in the concentrated extract. To be quite certain that no lead from the glass could find its way into solution by this procedure, the very stringent test was made of extracting 5 grams of finely powdered glass for some hours with water and testing the residue after evaporation to dryness. The glass used had at some previous time been exposed to the action of radium emanation, and was of a deep purple colour. No lead was found in the extract, though analysis proved its presence in the glass.

Other sources of error lay in the possible presence of lead in the mercury sealing the tube, and in the reagents used for the test. No lead could be detected in the mercury and the reagents were carefully purified beforehand. In order to carry out the test the capillary tube containing the radio-active matter was cut into two portions, a longer one containing most of the solution, and a shorter portion in which the undissolved crystals remained. The solution in the longer portion was allowed to evaporate on a silica microscopic slide, and one portion of the drop obtained was tested for lead by the triple nitrite test and another tested with potassium chromate. In both cases the presence of lead was indubitably proved, but the quantity present was small. The short end containing the crystals was then fractured and the fragments extracted with water to which a drop of acetic acid had been added. The evaporated extract

which left a scarcely visible residue was intensely radio-active, and from its solution a minute trace of a dark-coloured sulphide was precipitated by sulphuretted hydrogen. This latter was separated by centrifuging the solution in a capillary tube, dissolved in a drop of nitric acid, and tested by the Behrens method. The drop yielded a copious crop of triple nitrite crystals, and the amount of lead present was estimated at 1/4000 milligram. Now in the whole of the disintegration products in the tube only about 1/7000 milligram of radium-G was contained, and, further, only a fraction of the total matter was used for the test. Hence it seems probable that radium-G and radium-D both form a characteristically crystalline triple nitrite identical with that formed by lead.

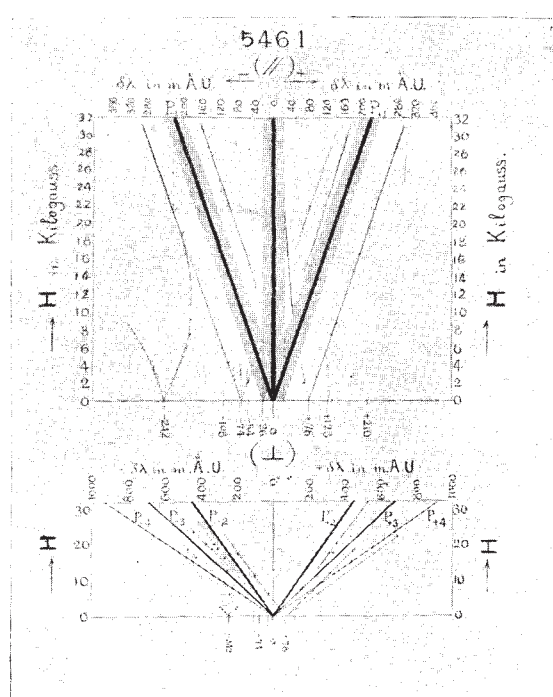
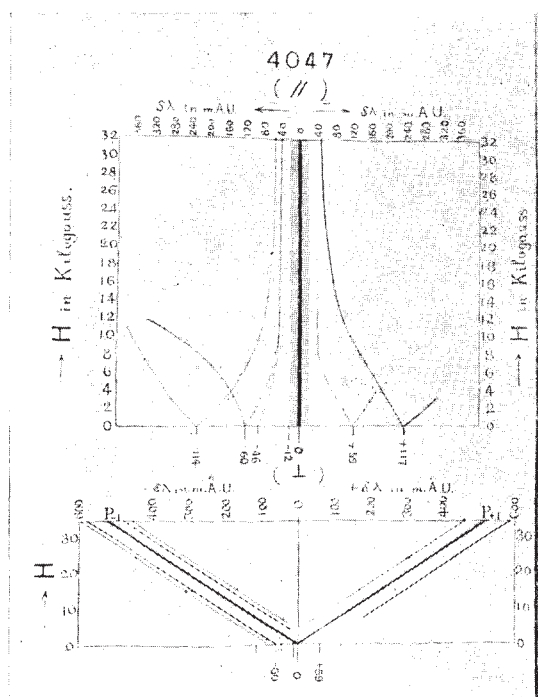
An attempt was made to determine what fraction of the whole of the matter originally in the tube was present in the drop tested, by comparing the β -radiation of the various portions, but no great trustworthiness could be placed on the measurements at the time,

found in the yellow line a satellite having anomalous character. Wendt noticed four characteristic lines in strong fields, but the satellites from which these lines proceed could not be identified.

Owing to extreme complexity in the distribution of lines when the field strength is increased, we have as yet no continuous observation indicating the position of satellites of mercury lines in different magnetic fields.

To fill in this gap, we made measurements on the satellites of the violet line 4047 and the green line 5461, up to the field of 30 kilogauss, and arrived at an unexpected result that the satellites show anomalous Zeeman effect, either as regards intensity or the mode of separation, and in nearly all cases both combined.

The instrument used was an echelon grating, but it was sometimes crossed with a Fabry-Perot air plate or a Lummer-Gehrcke plane-parallel plate to eliminate the false lines. From a large number of photographs



since the chloride of radium-E has probably a different solubility to the chlorides of D and G. In a few months' time, however, when the β -radiation of E has reached its equilibrium value a repetition of the measurements should lead to a definite conclusion. Hence, excluding the possibility of undetected sources of error, one must conclude that the slow change products of the disintegration of niton contain a body behaving like lead, and, further, that this body is either radium-D alone or a mixture of radium-D and radium-G. Thus the investigation, so far as it has gone at present, tends further to support the theories of Soddy and of Fajans.

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Anomalous Zeeman Effect in the Satellites of Mercury Lines.

GEHRCKE and Baeyer, Lunelund, and McLennan showed that the satellites of some mercury lines are separated in a regular manner in weak fields; Gmelin

of transverse effects obtained in different fields, which were mostly uniform but sometimes heterogeneous, the positions of the satellites were plotted and traced into continuous curves; these are given in the accompanying figures, for components vibrating parallel and perpendicular to the field. The branches of the principal lines are indicated by P, and shaded to show the actual breadth; the positions of satellites in zero field are marked on the axis of abscissa by lines proportional to the intensity.

A glance at the figures for parallel components show that the separation is not generally proportional to the magnetic field. The satellites of 4047 are characterised by approaching the central principal line asymptotically, while in weak fields, the change in wave-length is quite rapid. The most remarkable of them is the satellite at -60 m.Å.U. from the principal; the branch towards the positive side is approximately a parabola with vertical axis, and that towards the negative side a similar curve with horizontal axis; consequently the change wrought by magnetic field is